NASA/GSFC Testing of Li-Ion Cells: Update

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2000 NASA Aerospace Battery Workshop
Huntsville, Alabama
November 14-16, 2000

Objective

- Cell Characterization
  - Capacity
  - Self-discharge
  - Mid-discharge voltage
- Determination of Cycling Performance as a Battery Pack under LEO regime
  - Number of cycles
  - Charge voltage
  - Temperature

Cells Under Study

- Prismatic Cells
  - 20 AH Yardney
  - 1.5 AH Wilson Greatbatch
- Cylindrical Cells
  - 12 AH, 4 AH and 1.25 AH SAFT
- Polymer cells
  - 3 AH Alliant Tech.
  - 8 AH Lithium Technology, Inc.

Characterization Data

- Self-discharge - 72 hours charged open-circuit stand
  - Yardney = 1.4%
  - SAFT =1.4%
  - Alliant Tech (ATK) = 2%
  - Wilson Greatbatch (WG) =1.4%
- Capacity Decrease when the discharge rate is increased to C/2 from C/5
  - Yardney - 2%
  - SAFT - 0.9%
  - ATK - 2%
  - WG - 25%

Characterization Data -Contd.

- Mid-discharge voltages at C/2 discharge rate
  - Yardney = 3.51V
  - SAFT = 3.56V
  - ATK = 3.54 V
  - WG = 3.65V
- Cell impedance (mohms) at 50% SOC
  - SAFT = 1.74
  - Yardney = 10.2
  - ATK = 51
  - WG = 68

Characterization Data -Contd.

- Capacity at 0°C in percentage of capacity at 25°C

  - Yardney = 92%
  - SAFT = 91%
  - WG = 91%
  - ATK = 51%

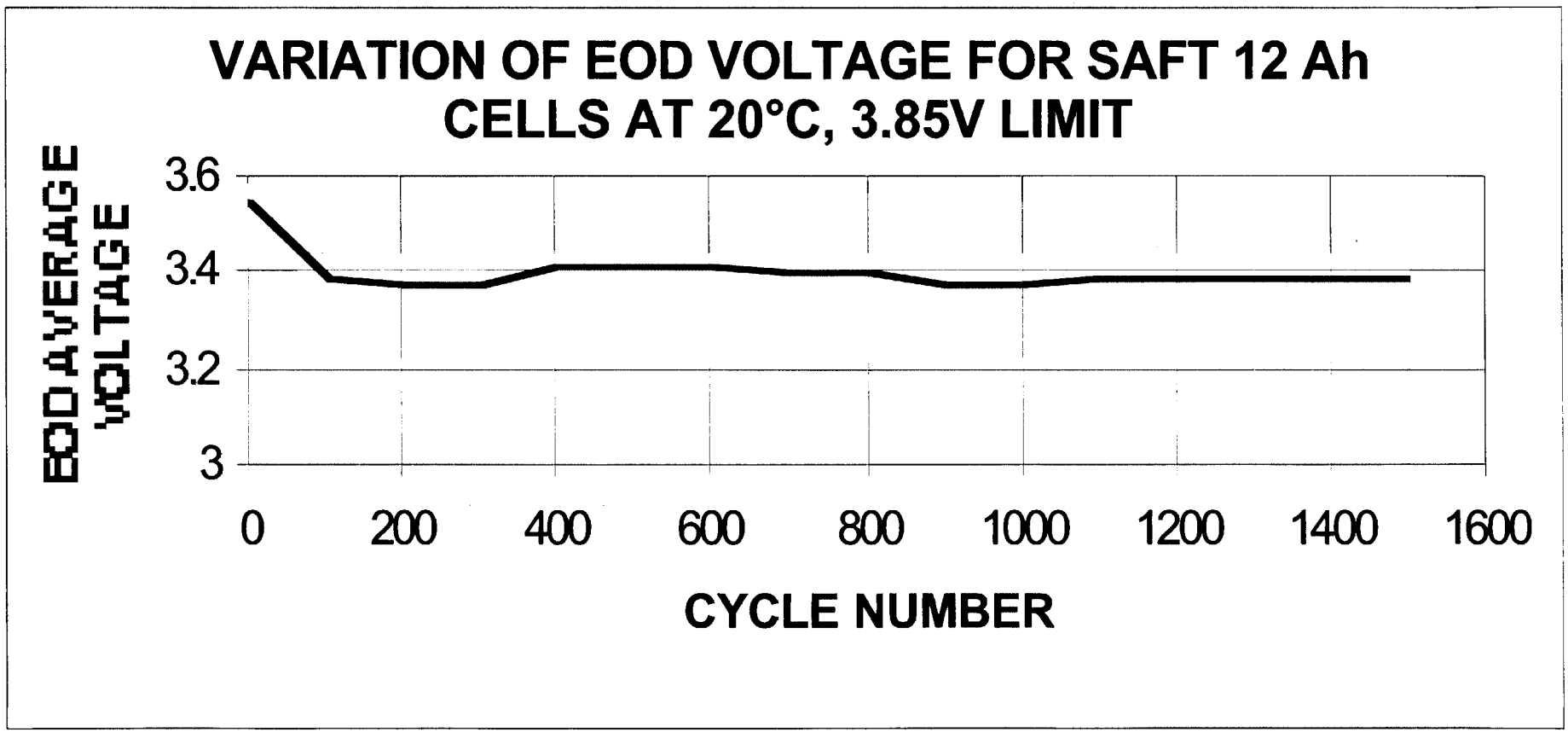
LEO Cycling: Conditions

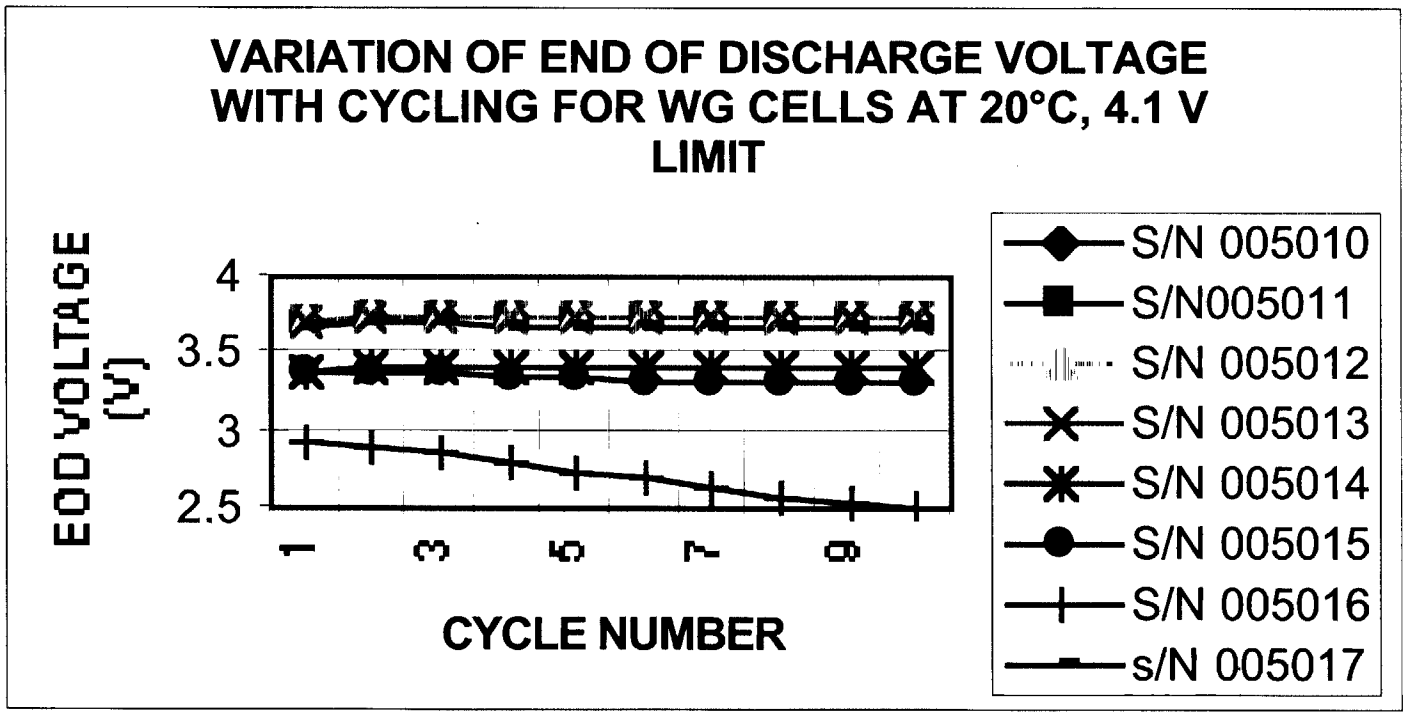
- Continuous cycling in a regime consisting of 30 min. discharge and 60 min. charge at the rate of 16 cycles/day
- Temperature = -20°C to 40°C
- Depth of discharge = 40%
- Charge voltage clamped at a Battery/Pack voltage at C/2 rate with current taper
- Recharge ratio = 1-1.01

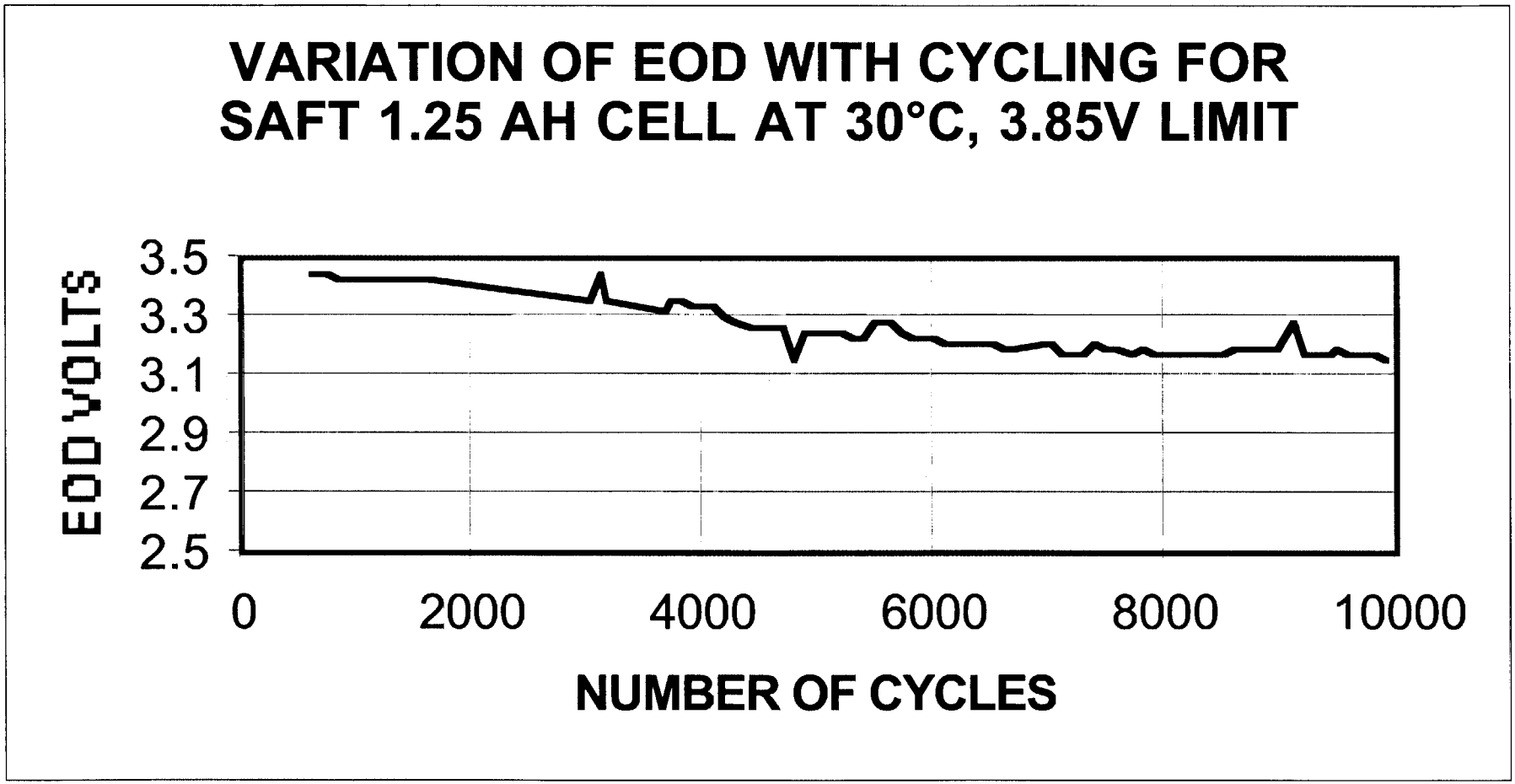
LEO Cycling: Data

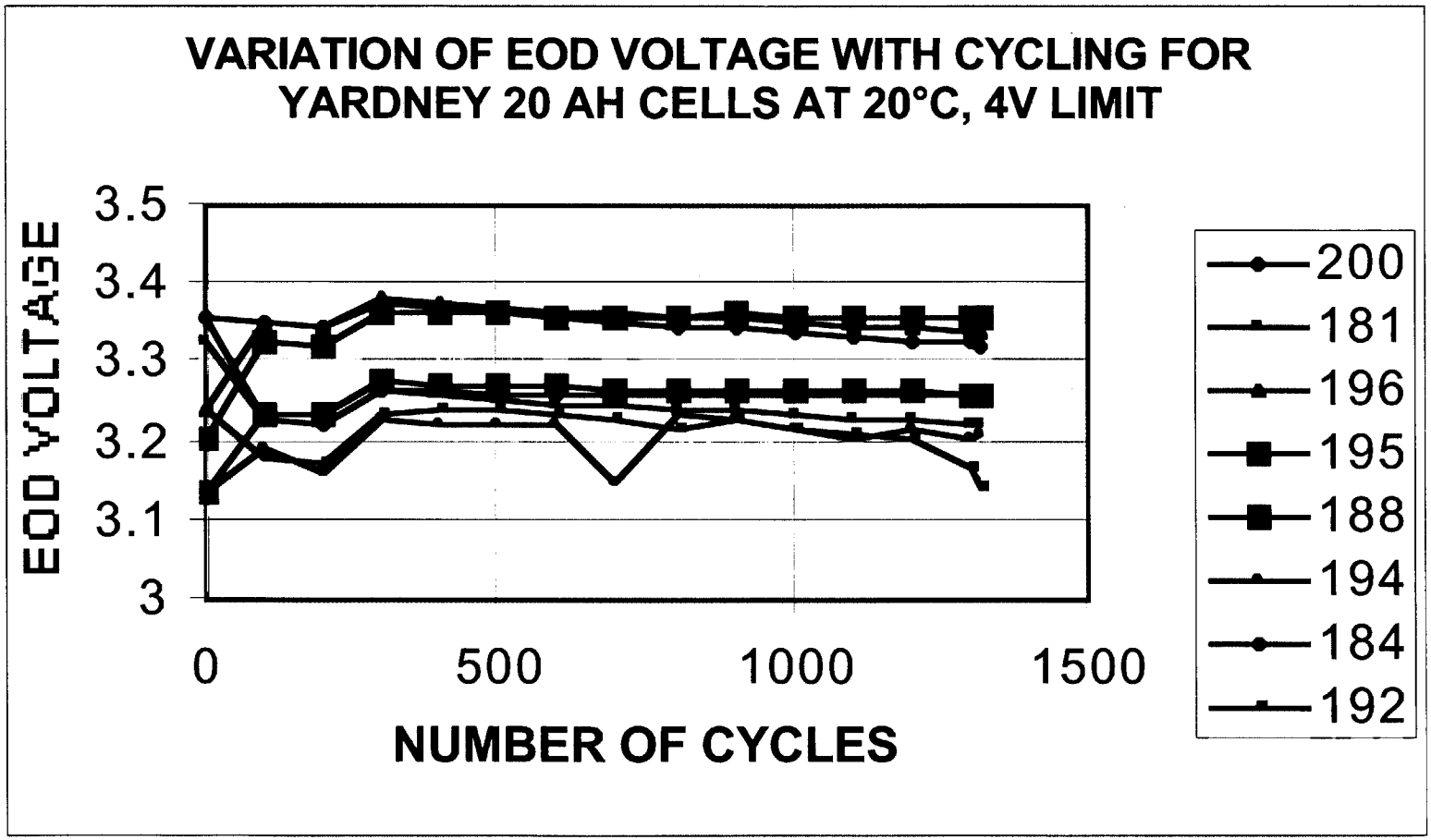
Number of cells and cell type	CAP, AH AT 25°C	Charge V limit	CYCLES	STATUS
8 - SAFT12AH	11.4	3.85	1514	Continuing
8 - Yardney 20AH*	24.9	4	2514	Continuing
5 - Alliant Tech 3AH	2.06	4	2359	Discontd
8 - WG 1.5AH	1.43	4.1	10	Discontd
8 - Li-Tech 8AH	7.1	4.1	2	Discontd
2 - SAFT 4AH	4	3.85	6269	Continuing
2 - SAFT 1.25AH	1.3	3.85	10092	Continuing

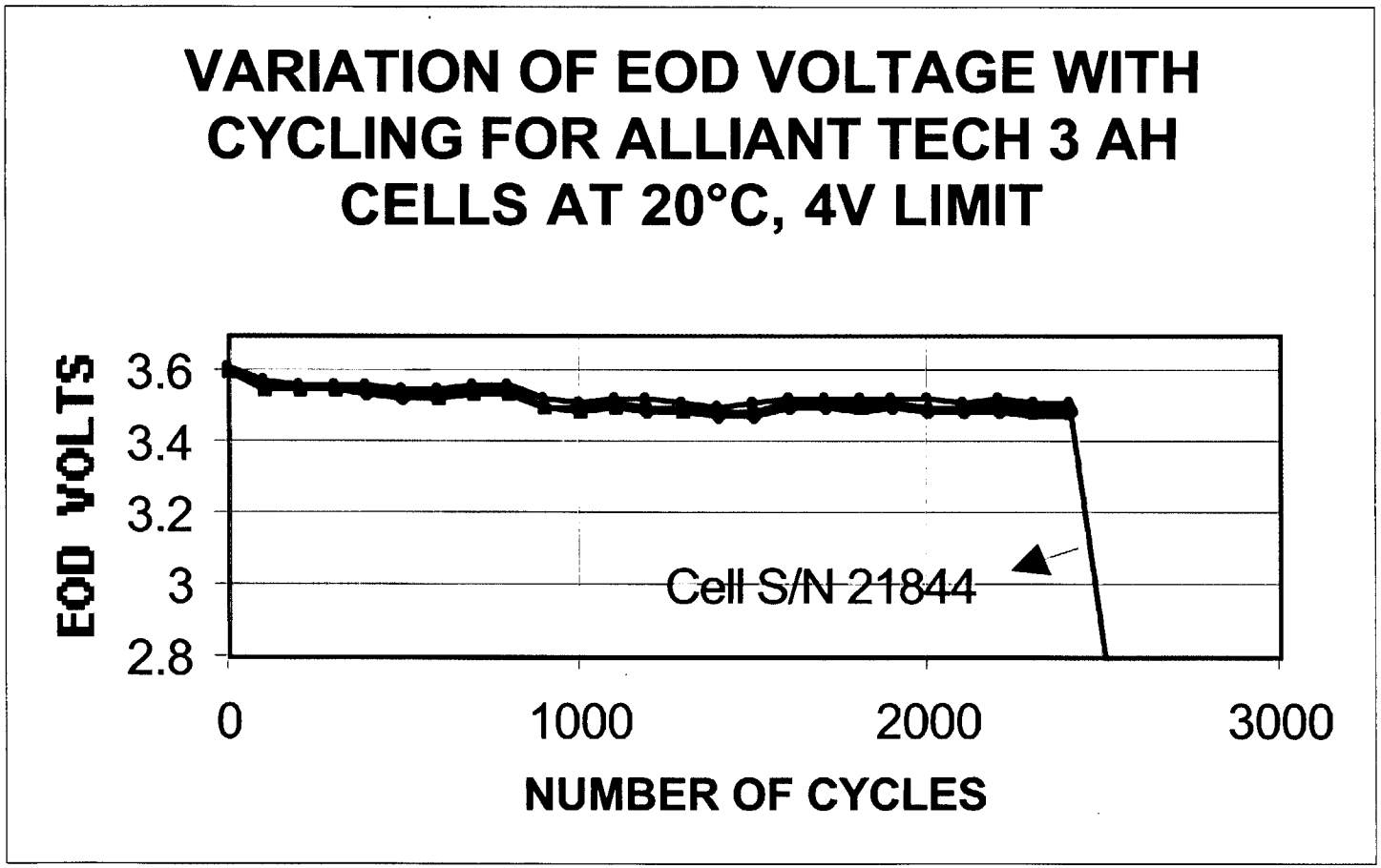
* Cells 192,194,195 and 196 have previously completed 2966 cycles


VARIATION OF EOD VOLTAGE FOR SAFT 12 Ah CELLS AT 20°C, 3.85V LIMIT
BOD AVERAGE VOLTAGE
3.6
3.4
3.2
3
0
200
400
600
800
1000
1200
1400
1600
CYCLE NUMBER


VARIATION OF END OF DISCHARGE VOLTAGE WITH CYCLING FOR WG CELLS AT 20°C, 4.1 V LIMIT
EOD VOLTAGE (V)
4
3.5
3
2.5
1
3
5
7
9
CYCLE NUMBER
S/N 005010
S/N005011
S/N 005012
S/N 005013
S/N 005014
S/N 005015
S/N 005016
s/N 005017

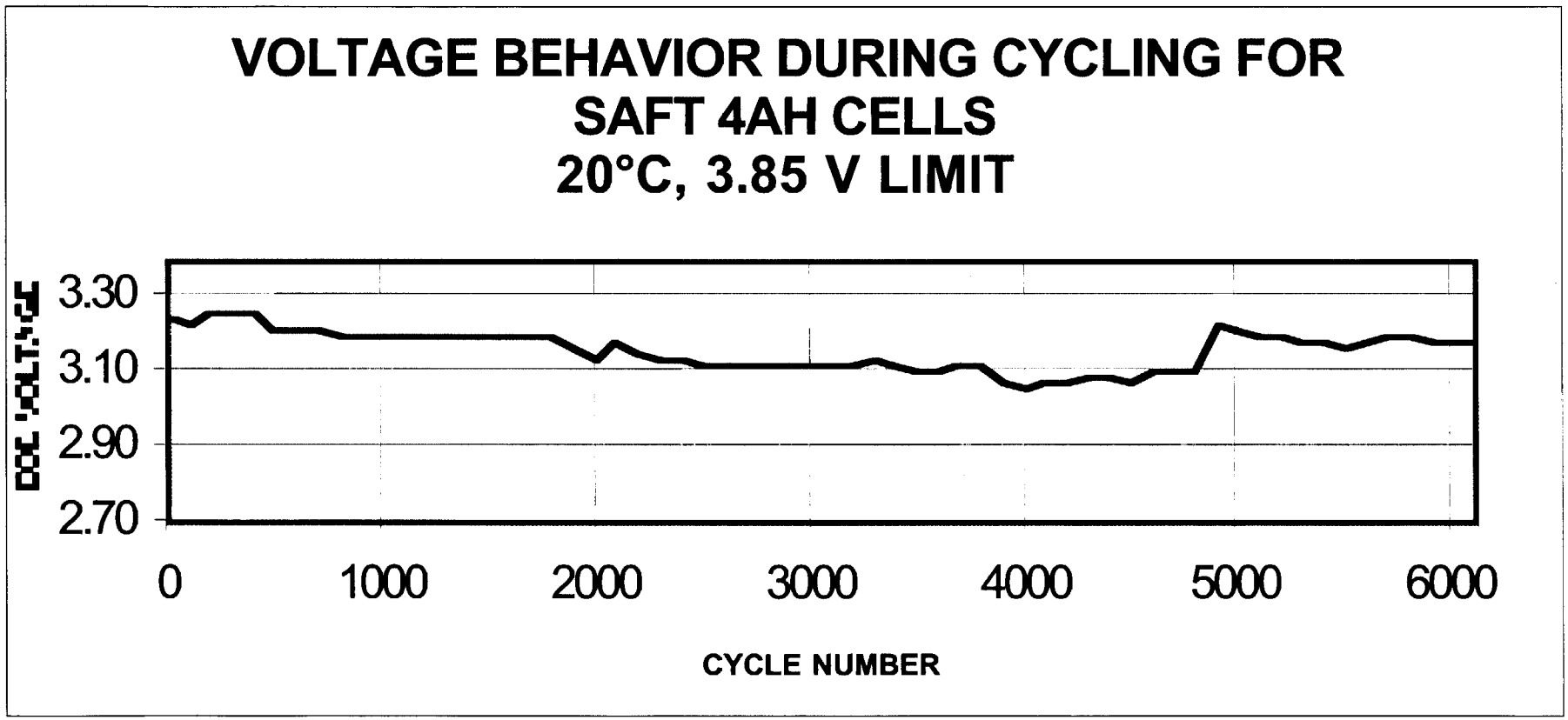

VARIATION OF EOD WITH CYCLING FOR
SAFT 1.25 AH CELL AT 30°C, 3.85V LIMIT
EOD VOLTS
3.5
3.3
3.1
2.9
2.7
2.5
0
2000
4000
6000
8000
10000
NUMBER OF CYCLES


VARIATION OF EOD VOLTAGE WITH CYCLING FOR YARDNEY 20 AH CELLS AT 20°C, 4V LIMIT
EOD VOLTAGE
3.5
3.4
3.3
3.2
3.1
3
0
500
1000
1500
NUMBER OF CYCLES
200
181
196
195
188
194
184
192


VARIATION OF EOD VOLTAGE WITH CYCLING FOR ALLIANT TECH 3 AH CELLS AT 20°C, 4V LIMIT
EOD VOLTS
3.6
3.4
3.2
3
2.8
Cell S/N 21844
0
1000
2000
3000
NUMBER OF CYCLES

PERFORMANCE TWO 2-CELL SAFT 4 AH BATTERIES

Temp °C	Number of cycles	End of dischg voltage	Comments
30	4289	3.217	cell charged to 3.85V
40	550	3.266	cell charged to 3.85V
0	560	2.816	cell charged to 4.1V
-20	2	2	cell charged to 4.3V
-10	39	2.755	cell charged to 4.48V
10	442	3.039	cell charged to 4.1V
20	6157	3.17	cell charged to 3.85V


VOLTAGE BEHAVIOR DURING CYCLING FOR
SAFT 4AH CELLS
20°C, 3.85 V LIMIT
3.30
3.10
2.90
2.70
0
1000
2000
3000
4000
5000
6000
CYCLE NUMBER

Conclusions

- The self-discharge rate of Li-ion cells is 1.4% in the 72-hr charged open-circuit stand test that is superior to NiCd and NiH2 Batteries
- Charge acceptance of the cells decreases with temperature
- Cells cannot be cycled in a 90-minute orbit and 40% DoD at -10°C unless the voltage limit on charge is increased to 4.5V
- Limited cycling excursion to -20°C (low temperatures) does not appear to impair the cycling behavior at 20°C
- The solid electrolyte and gel electrolyte cells' performance is inferior to the liquid electrolyte cells under our LEO test conditions
- The data suggests the potential use of a battery level charging by monitoring and managing the cell parameters